CLAIMS

I claim:

1. A method of determining the location of robbed bits in an echo signal that has passed through a communications network, a portion of which network is digital, said method comprising the steps of:

(1) transmitting a known training signal, i(n), over a link with a remote device on said communications network in the absence of any data being transmitted over said link by said remote device, said training signal comprising a plurality of portions into which a robbed bit may be inserted in a known location within said portions;

(2) detecting the amplitudes of the echo of said portions of said training signal that are received over said network, and determining from said amplitudes which portions of said echo include a robbed bit; and

(3) generating a signal indicating the location of said robbed bit in said echos.

2. The method of claim 1 wherein, within said digital portion of said network, data is comprised of a plurality of samples, each sample including a plurality of bits and wherein said network inserts said robbed bits into the least significant bit position of one of said samples at a known

interval of every m samples, where m is an integer, and said amplitudes are determined on a modulo m basis.

3. The method of claim 2 wherein step (2) comprises the steps of:

(2.1) generating an echo cancellation signal, r'(n), from said training signal, i(n), that emulates the impulse response of said link by use of a finite impulse response filter having a plurality of filter coefficients, C(n);

(2.2) generating from said known training signal, i(n), and said filter coefficients, C(n), a modulo reference signal, S(n), having a modulo corresponding to the frequency of robbed bit signaling protocol in said communications network;

(2.3) subtracting said echo cancellation signal, r'(n), from an echo of said training signal, r(n), to generate an error signal, e(n); and

(2.4) generating from said error signal and said modulo reference signal, a level adapter signal, H(n), said level adapter signal comprising a plurality of amplitude values, each corresponding to a portion of said error signal, e(n), said amplitude values being indicative of the existence of a robbed bit in said portion of said error signal;

wherein n is an integer representing said different portions of said training signal.

4. The method of claim 3 wherein said training signal is an ideal, two level, pseudo random, signal.

5. The method of claim 3 wherein step (2) further comprises the step of:

(2.5) generating a modulo and adjust reference signal, $i'(n)$, from said known training signal, $i(n)$, and said level adapter signal, $H(n)$, said modulo and adjust reference signal being equivalent to the training signal, $i(n)$, with respect to portions into which the said communication network has not inserted a robbed bit and being different from the training signal with respect to portions into which the said communications network has inserted a robbed bit.

6. The method of claim 5 wherein step (2.5) comprises solving;

$$i'(n) = \mathrm{sign}(i(n))(i_0 + h_{\mathrm{mod}\,\delta(n)}\delta)$$

$$\mathrm{sign}(t) = \begin{cases} +1 & t > 0.0 \\ 0 & t = 0.0 \\ -1 & t < 0.0 \end{cases}$$

where

δ is the difference in amplitude of an $i(n)$ corresponding to a portion that does not include a robbed bit and the

amplitude of an i(n) corresponding to a portion that not includes a robbed bit.

7. The method of claim 6 wherein step (2.1) comprises solving:

$$r'(n) = C^T(n) I'(n)$$

where

$C^T(n) = [c_{N-1}(n),\ c_{N-2}(n),\ \ldots\ldots,\ c_1(n),\ c_0(n)]$

$I'^T(n) = [i'(n-(N-1)),\ i'(n-(N-2)),\ \ldots,\ i'(n-1),\ i'(n)]$, and

N is the length of said finite impulse response filter.

8. The method of claim 7 wherein step (2.1) further comprises solving;

$$s_l(n) = \sum_{m=0}^{\frac{[N-\mathrm{mod}6(N)]}{6}} c_{\mathrm{mod}6(n-l)+6m}\, i(n-\mathrm{mod}6(n-l)-6m), \qquad \text{with } 0 \le l \le 5$$

to generate said filter coefficients C(n).

9. The method of claim 8 wherein step (2.4), comprises solving;

$$H(n+1) = H(n) - 2\beta\ e(n) S(n)$$

where

β is the step-size used for updating the level adapter coefficients.

10. The method of claim 9 wherein step (2.2), comprises solving;

$$C(n+1)=C(n)+2\alpha e(n)I'(n) \qquad \text{(Eq. 2)}$$

where

α is the step-size used for updating the coefficients of the finite impulse response filter, C(n).

11. The method of claim 5 wherein step (2) is first performed without performing step (2.4) and wherein said level adapter signal, H(n), is set to a predetermined constant value and then, subsequently, step (2.4) is performed.

12. A method of canceling echo in a transceiver coupled to a communications network that inserts robbed bits into signals on said network, said method including compensation for said inserted robbed bits, said method comprising the steps of:

(1) providing a path between a transmitter and a receiver of said transceiver whereby signals transmitted onto said network by said transmitter are also provided onto said path;

(2) determining a round trip delay for signals transmitted via said network;

(3) determining the location of robbed bits inserted by said network by transmitting a known training signal, i(n), over a link on said network in the absence of any other data being transmitted on said link, detecting the amplitudes of

portions of the echo of said training signal that is received from said network, and determining from said amplitudes which portions of said echo include a robbed bit;

(4) delaying said signal on said path by a round trip delay through said network;

(5) inserting into said signal on said path compensation for said robbed bits inserted into said transmitted signals;

(6) generating from said delayed and robbed bit compensated signal on said path an echo cancellation signal; and

(7) subtracting said echo cancellation signal from signals received via said network before reception at said receiver.

13. The method of claim 12 wherein, within said digital portion of said network, data is comprised of a plurality of samples, each sample including a plurality of bits and wherein said network inserts said robbed bits into the least significant bit position of one of said samples at a known interval of every 6 samples.

14. The method of claim 13 wherein step (3) comprises the steps of:

(3.1) generating an echo cancellation signal, $r'(n)$, from said training signal, $i(n)$, that emulates the impulse response

of said link by use of a finite impulse response filter having a plurality of filter coefficients, C(n);

(3.2) generating from said known training signal, i(n), and said filter coefficients, C(n), a modulo reference signal, S(n), having a modulo corresponding to the frequency of robbed bit signaling protocol in said communications network;

(3.3) subtracting said echo cancellation signal, r′(n), from an echo of said training signal, r(n), to generate an error signal, e(n); and

(3.4) generating from said error signal and said modulo reference signal, a level adapter signal, H(n), said level adapter signal comprising a plurality of amplitude values, each corresponding to a portion of said error signal, e(n), said amplitude values being indicative of the existence of a robbed bit in said portion of said error signal;

wherein n is an integer representing said different portions of said training signal.

15. The method of claim 14 wherein said training signal is an ideal, two level, pseudo-random, signal.

16. The method of claim 15 wherein step (3) further comprises the step of:

(3.5) generating a modulo and adjust reference signal, i′(n), from said known training signal, i(n), and said level adapter signal, H(n), said modulo and adjust reference signal

being equivalent to the training signal, i(n), with respect to portions into which the said communication network has not inserted a robbed bit and being different from the training signal with respect to portions into which the said communications network has inserted a robbed bit.

17. The method of claim 16 wherein step (3.5) comprises solving;

$$i'(n) = \mathrm{sign}(i(n))(i_0+h_{\mathrm{mod}6(n)}\delta)$$

$$\mathrm{sign}(t)=\begin{cases} +1 & t>0.0 \\ 0 & t=0.0 \\ -1 & t<0.0 \end{cases}$$

where

δ is the difference in amplitude of an i(n) corresponding to a portion that does not include a robbed bit and the amplitude of an i(n) corresponding to a portion that not includes a robbed bit.

18. The method of claim 17 wherein step (2.1) comprises solving:

$$r'(n)=C^T(n)I'(n)$$

where

$$C^T(n)=c_{N-1}(n)\ c_{N-2}(n)\ \ldots\ldots,\ c_1(n),\ c_0(n)]$$

$$I'^T(n)=[i'(n-(N-1)),\ i'(n-(N-2)),\ \ldots,\ i'(n-1),\ i'(n)],$$ and

N is the length of said finite impulse response filter.

19. The method of claim 18 wherein step (3.1) further comprises solving;

$$s_l(n) = \sum_{m=0}^{\frac{[N-\mathrm{mod}\,6(N)]}{6}} C_{\mathrm{mod}\,6(n-l)+6m}\, i(n - \mathrm{mod}\,6(n-l) - 6m), \qquad \textit{with } 0 \le l \le 5$$

to generate said filter coefficients C(n).

20. The method of claim 19 wherein step (3.4), comprises solving;

$H(n+1) = H(n) - 2\beta\ e(n)S(n)$

where

β is the step-size used for updating the level adapter coefficients.

21. The method of claim 20 wherein step (3.2), comprises solving;

$C(n+1)=C(n)+2\alpha e(n)I'(n)$

where

α is the step-size used for updating the coefficients of the finite impulse response filter, C(n).

22. The method of claim 16 wherein step (3) is first performed without performing step (3.4) and wherein said level

adapter signal, H(n), is set to a predetermined constant value and then, subsequently, step (3.4) is performed.

23. An apparatus for determining the location of robbed bits in an echo signal that has passed through a communications network, a portion of which network is digital, said apparatus comprising:

a training signal generator for generating a known training signal, i(n), said training signal comprising a plurality of portions into which a robbed bit may be inserted in a known location within said portions;

a transmitter for transmitting said training signal, i(n), over a link with a remote device on said communications network in the absence of any data being transmitted over said link by said remote device;

a level adapter for generating signals, H(n), indicative of the amplitudes of the echo of said portions of said training signal that are received over said network; and

a robbed bit detector for determining from said amplitudes which portions of said echo include a robbed bit; and generating a signal indicating the location of said robbed bits in said echo.

24. The apparatus of claim 23 further comprising:

an echo canceller that generates an echo cancellation signal, r′(n), from said training signal, i(n), by use of a

finite impulse response filter having a plurality of filter coefficients, C(n), said echo cancellation signal emulating the impulse response of said link;

a modulo reference signal echo tap generator that generates from said known training signal, i(n), and said filter coefficients, C(n), a modulo reference signal, S(n), having a modulo corresponding to the frequency of robbed bit signaling protocol in said communications network;

a subtractor for subtracting said echo cancellation signal, r′(n), from an echo of said training signal, r(n), to generate an error signal, e(n);

wherein said level adapter generates said level adapter signal, H(n), from said error signal and said modulo reference signal, said level adapter signal comprising a plurality of amplitude values, each corresponding to a portion of said error signal, e(n), said amplitude values being indicative of the existence of a robbed bit in said portion of said error signal; and

wherein n is an integer representing said different portions of said training signal.

25. The apparatus of claim 24 wherein said training signal is an ideal, two level, pseudo random, signal.

26. The apparatus of claim 25 further comprising:

a modulo and adjust reference signal generator for generating a signal, i'(n), from said known training signal, i(n), and said level adapter signal, H(n), said signal being equivalent to the training signal, i(n), with respect to portions into which said communication network has not inserted a robbed bit and being different from the training signal with respect to portions into which the said communications network has inserted a robbed bit.